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PROCEDURES

FOR

SAMPLING TAILINGS

FROM

PLACER GOLD SLUICE OPERATIONS

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1. INTRODUCTION

This report is prepared at the request of Mr Tad Cienski, PEng, Senior Engineer Mineral Processing with the Canada Centre for Minerals & Energy Technology, and submitted in accordance with the guidelines from the Science and Professional Services Directorate, Supply and Services Canada as specified in Contract Serial No 23440-7-9156/01-SQ under the title "Procedures for Sampling Tailings from Placer Gold Sluice Operations".

The report is based on observations that were made during visits with Mr Tad Cienski of CANMET and Mr Randy Clarkson, PEng, Project Manager with the Klondike Placer Miners Association, to placer mining operations in the vicinity of Dawson City in the Yukon from September 2nd to 5th, 1987, on discussions with operators and between members of this team, and on theoretical concepts and practical considerations that apply to sampling of slurries, and to the accuracy and precision of test data for slurry samples.

The purpose of the sampling program is to measure the amount of fine gold in tailings, to determine its distribution over a range of particle size fractions, and to provide composite samples for laboratory testing of recovery techniques for such fine gold. The program is designed to generate unbiased data with known precision characteristics on the basis of test samples from manually collected gross samples.

The report is divided into chapters that each deal with an element of the sampling procedure, and each chapter is divided into sections that address a specific subject. The theory that applies to sampling of slurries, and the principles of experimental design will be reviewed. Sampling regimes and methods that are suited for the collection of unbiased primary increments from tailings of different types of sluice boxes, suitable sample division and preparation procedures, and the statistical evaluation of test data will be discussed in detail.

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2. OBJECTIVE

The objective of this sampling program is to measure the amount of fine gold in tailings from different types of sluice boxes that are presently used at placer gold mining operations in the Bonanza Creek and Hunter Creek regions, and in the Sixty Mile River region. The amount of fine gold in tailings is a function of numerous variables and factors that will be addressed in separate sections of this report.

Elements of metrology as applied to sampling, sample preparation and testing of slurries will be introduced. Concepts such as the accuracy and precision of a measurement will be defined, and parameters that quantify such characteristics for this measurement procedure will be presented. In addition to a review of sampling methods and regimes, division and preparation procedures for gross samples, and measurement techniques for test samples, the sampling theory that applies to the distribution of gold particles in slurries, and elements of mathematical probability and applied statistics, will be discussed.

Placer gold operations that process unscreened gravel are more likely to lose fine gold than those that remove coarse gravel first to maintain a uniform flow through the sluice box. Therefore, the tailings from an unscreened feed are expected to contain a larger amount of fine gold than those from a screened feed but are much more difficult to sample. Under such conditions a set of unbiased primary increments can only be obtained after the coarsest gravel is removed prior to sampling. A suitable manual sampling method for unscreened dirt will be described.

The sampling program is designed to measure fine gold in the tailings of each sampling unit. The most reliable estimate of its head grade would be obtained if the sluice box were cleaned after a sampling unit is processed but this procedure is impractical and expensive. However, consideration should be given to cleaning the sluice box before and after all sampling units at a certain placer operation are processed.

3. TERMINOLOGY

In this section will be introduced terminology that is used to describe the sampling program. The accuracy and precision characteristics of a measurement such as the amount of fine gold in tailings will be defined. Frequently used terms such as sampling unit, sampling regime, and the different variance components that contribute to the uncertainty of a measurement process will be introduced.

3.1. Accuracy

A criterion to assess the closeness of agreement between the estimated quality parameter and its unknown true value.

3.2. Precision

A measure for random variations between replicate test data.

3.3. Sampling Unit

A quantity of material that is represented by a set of primary increments.

3.4. Sampling Regime

A sample collection scheme in terms of a number of primary increments, their average mass or volume, their spacing in mass or time, and the mode of collection (either manual or mechanical).

3.5. Total Variance

The sum of the variance of sampling, sample preparation, and measurement for the amount of fine gold in tailings.

3.6. Sampling Variance

A measure for random variations between fine gold contents of primary increments.

3.7. Composition Variance

A measure for random variations between compositions of single particles, and thus for the composition heterogeneity.

3.8. Distribution Variance

A measure for random variations in the distribution of gold particles of all sizes throughout the sampling unit, and thus for the distribution heterogeneity.

3.9. Variance of Preparation

A measure for random variation between fine gold contents of subsamples that are obtained from a gross sample by a process of division.

3.10. Variance of Analysis

A measure for random variations between fine gold contents of test samples that are obtained from a gross sample or subsample by a process of division.

4. DESCRIPTION

In this section the theory and practice that are applicable to sampling of tailings from a sluice box will be discussed. For a more detailed review of the sampling theory for bulk solids reference is made to the literature on this subject. The variance for the amount of fine gold in tailings is the most basic measure for precision but more transparent measures such as 95% confidence intervals, 95% confidence ranges, and coefficients of variation, will also be discussed.

A reliable precision estimate for the amount of fine gold in slurry samples can only be obtained if the variance of sampling, preparation, and measurement is known. An efficient method to routinely determine this variance will be introduced.

4.1. Accuracy

Accuracy is an abstract concept that deals with the reliability of test data for a sampling unit in terms of the closeness of agreement between such an estimate and its unknown true value. The definition implies that accuracy is a descriptive attribute that cannot be quantified. Only a lack of accuracy can be measured, quantified, and expressed in terms of a systematic error or bias. Hence, the measured amount of fine gold in the tailings of a sampling unit is either accurate or biased.

Testing for bias plays an important role in experimental design. Bias detection limits for an experiment are a measure for its sensitivity to detect a systematic error. Bias tests can also be applied to verify whether measurements are compatible if the variance for each is known. This sampling program will require that differences between two (2) or more measurements, or between averages for sets of measurements, be tested for statistical significance. Hence, the test determines, in terms of probabilities, whether such differences are due to random variations in sampling, division and testing, or due to significant differences between fine gold contents in tailings from different sampling units.

Generally, the relative accuracy of test data is assured by selecting unbiased systems and procedures, and by executing all stages in a measurement process without introducing systematic errors. In this case only the relative accuracy of test data rather than their absolute accuracy can be ensured. Thus accuracy cannot be measured directly but a lack of accuracy for a measurement, and its degree of precision, can be expressed in clearly defined mathematical terms.

4.2. Precision

Precision is a numerical value for the magnitude of random variations in a measurement process. The most fundamental measure for precision is the variance. Derived measures are the standard deviation which is the square root of the variance, the coefficient of variation which is equal to the standard deviation as a percentage of the mean, and confidence intervals and ranges at certain probability levels.

Coefficients of variation (CV in %), confidence intervals (CI's), and confidence ranges (CR's) are more transparent measures for precision than variances and standard deviations. In science and engineering 95% confidence intervals (95% CI's) and 95% confidence ranges (95% CR's) are used most frequently. For a small number of test data a tabulated t-value, at the 95% probability level and with n-1 degrees of freedom, rather than the tabulated z-value from the normal distribution, is used to calculate 95% CI's and 95% CR's.

The following formula applies to the calculation of the variance for a single measurement from the mean of absolute differences between a series of four (4) or more duplicates:

$$var(x) = (\pi/4) * [\Sigma(|\Delta x_i|)/n]^2$$

in which: $var(x)$ = variance for a single measurement
$|\Delta x_i|$ = absolute difference between ith data pair
n = number of paired measurements

The coefficient of variation is calculated from this variance and the estimate for the parameter of interest with the following formula:

$$CV \text{ in } \% = var(x)^{\frac{1}{2}} * 100/\bar{x} = sd(x) * 100/\bar{x}$$

in which: CV in % = coefficient of variation for a single test
var(x) = variance for a single measurement
sd(x) = standard deviation
$\bar{x}$ = average measurement

The 95% confidence interval (95% CI), for a single measurement or for the mean of a set of measurements, is obtained by multiplying the standard deviation with either a tabulated t-value with the appropriate number of degrees of freedom, or with the tabulated z-value from the normal distribution, so that the following formulae apply:

$$95\% \text{ CI} = var(x)^{\frac{1}{2}} * t0.95;n-1 = sd(x) * t0.95;n-1$$

or: $$95\% \text{ CI} = var(x)^{\frac{1}{2}} * z0.95 = sd(x) * z0.95$$

in which: 95% CI = 95% confidence interval
var(x) = variance
sd(x) = standard deviation
t0.95;n-1 = t-value
n-1 = degrees of freedom
z0.95 = z-value (1.96)

The symbol var($\bar{x}$) applies to the variance for the mean of replicates. Variances too are estimates to which confidence intervals apply so that the z-value of 1.96 can safely be rounded to a factor of two (.). For most applications the tabulated t-values will range from 2.2 up to 2.7.

Low and high limits of a 95% confidence range are obtained by adding to or deducting from a singe test data, or from the average of a series of test data, its corresponding 95% confidence interval as follows:

95% CR: LOW = x - 95% CI, or: $\bar{x}$ - 95% CI
95% CR: HIGH = x + 95% CI, or: $\bar{x}$ + 95% CI

in which: 95% CR: LOW = low limit of 95% confidence range
95% CR: HIGH = high limit of 95% confidence range
95% CI = 95% confidence interval
$\underline{x}$ = single measurement
$\bar{x}$ = mean of replicates

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Numerical examples of how to apply these formula, and when to use the variance of a single measurement or the variance for the mean of a set of measurements will be presented in Chapter 7. Experimental Design. Different formulae to calculate the variance from replicate measurements rather than from the mean of absolute differences between sets of duplicates can be found in textbooks on applied statistics.

4.3. Sampling Unit

A sampling unit is a quantity of material that is represented by a set of primary increments. In this case a sampling unit is the number of cubic yards (Vs in yd^3) that will be processed with a sluice box during a certain time period. The yardage of a sampling unit can be estimated either by counting the number of loads that is transferred into a sluice box during the sampling period, or by surveying its volume.

Surveying a section before and after a sampling unit is removed is less precise than surveying a symmetrical stockpile that is shaped with a bulldozer. At large placer operations in situ surveys are feasible but the precision for this technique at small placers will be very low. In terms of a coefficient of variation the precision of yardage estimates is expected to range from a low of 4% to a high of 8% which is equivalent to 95% confidence intervals from ± 8% up to ± 16%.

With the exception of the variability between the amount of fine gold in primary increments yardage estimates are the single most variable parameter in this sampling program. Variances of single measurements propagate in a composite measurement such as the difference between estimated volumes. For example, if the volume of a sampling unit were 1,000 yd^3, if a volume of 250 yd^3 were removed with the grizzly, and if these volumes were measured with a precision 5% respectively 8% in terms of a coefficient of variation, the variance for the difference of 750 yd^3 that was processed with the sluice box would be: $(1{,}000 * 5/100)^2 * (250 * 8/100)^2 = 2{,}900$ for a standard deviation of: $2{,}900^{\frac{1}{2}} = 53.9$ yd^3, and a CV of: $53.9 * 100/750 = 7.2\%$. Hence, the 95% CI for

this difference is: 53.9 * 2 = ± 108 yd^3 for a 95% CR from: 750 - 108 = 640 yd^3 up to: 750 + 108 = 860 yd^3.

The precision for the sampling unit of 1,000 yd^3 in terms of a 95% CI is: 2 * 1,000 * 5/100 = ± 100 yd^3 which is equivalent to a 95% CR from 900 yd^3 to 1,100 yd^3. This numerical example shows that deducting the volume of the coarse gravel that is removed with the grizzly, from the volume of a sampling unit causes the difference, and thus the yardage that was processed with the sluice box, to become even less precise than the total yardage.

Such low precision parameters imply that attempts to estimate coarse and fine fractions of sampling units complicate the sampling program without adding useful information to the data base. Therefore, only the total volume of each sampling unit (V_δ in yd^3) should be estimated as precisely as possible.

The amount of water that is used to process a sampling unit should also be estimated from the pump's capacity, the diameter of the feed pipe to the sluice box, and the time required to process the sampling unit. This parameter is measured in US gallons per minute so that the total amount of water used to process a sampling unit is V_ℓ gallons.

4.4. Sampling Theory

The total variance for the amount of fine gold in a gross sample that is collected from the tailings of a sluice box can be partitioned into variance components for collecting primary increments, for collecting a subsample from a gross sample, and for collecting a test sample from a subsample and measuring the parameter of interest in this test sample. The latter variance is referred to as the variance of analysis, even though the variance component for collecting a test sample from a gross samples or a subsample is included. However, the variance for this phase is usually only a small fraction of the variance of analysis.

In the case of fine gold in tailings the sampling variance cannot be partitioned into its composition and distribution components. For the composition variance is so much smaller than the distribution variance that the sampling variance is largely determined by different numbers of gold particles in primary increments rather than by differences in composition between all particles. In fact, the Poisson distribution is more suitable than the binomial or the normal distribution to determine the probability to find a certain number of gold particles in a primary increment, in a gross sample, in a subsample, or in a test sample.

The sampling model that applies to this test program is based on the additive properties of variances. If a set of n primary increments were combined into a single gross sample, if each gross sample were divided into a single subsample, and if gold were measured in a single test sample from the subsample, the total variance for the amount of fine gold in tailings would be:

$$var(t) = var(s)/n + var(p) + var(a)$$

in which:
- $var(t)$ = total variance
- $var(s)$ = sampling variance
- $var(d)$ = variance of division
- $var(a)$ = variance of measurement
- n = number of primary increments

Division of a variance, either by the number of primary increments, by the number of subsamples, or by the number of test samples, is based on the Central Limit Theorem which states that the variance for the average of n measurements is n times smaller than the variance for a single measurement. This relationship lies at the core of the sampling theory for bulk solids.

The sampling variance can be determined by measuring the gold content of single primary increments, and by calculating the variance between such test data. The amount of fine gold in tailings from placer mining operations varies between regions, between placer deposits, between sluice boxes, between sections in deposits, between strata in sections, between sampling units, and between primary increments. With so many nested classes of variables it would be of interest to determine the

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variance for the lowest class by measuring the fine gold content of each primary increment but the cost for this sampling program is prohibitive. A flow chart (see Chart B1 in Appendix B) shows this hierarchy of nested classes.

The most obvious alternative is to combine a set of primary increments for a sampling unit into a single gross sample. The disadvantage of this sampling method is that it does not generate any information on the precision of sampling, division and measurement. Yet, the sampling variance, the largest and single most important component of the total variance, should be determined so that a precision estimate for the amount of fine gold in each sampling unit can be calculated. Without a reliable precision estimate effective interpretation and evaluation of test data becomes impossible. Therefore, the sampling method for this test program should be based on collecting a pair of interpenetrating gross samples from each sampling unit.

4.5. Interpenetrating Samples

This sampling method is based on alternately storing primary increments in two (2) containers such that one sample consists of all odd-numbered increments while the other consists of all even-numbered increments. The mean of absolute differences between measurements on pairs of interpenetrating gross samples from four (4) or more sampling units is a measure for the total variance of this measurement process. The flow chart of sampling method is shown in Chart B2 of Appendix B.

By contrast, the mean of absolute differences between measurements on test samples from a single gross sample is only a measure for the variance of analysis which includes a small variance component for the collection of a test sample. Hence, a single gross sample does not generate any information on the sampling variance so that the precision of sampling, division and measurement cannot be estimated. Numerical examples of precision calculations that are based on interpenetrating gross samples, are included in Chapter 7. Experimental Design.

Collecting a pair of interpenetrating gross samples is only marginally more expensive than collecting a single gross sample but the cost for division and measurement becomes twice as high. Yet, interpenetrating samples provide so much more information that a higher cost is entirely justified. Testing pairs of samples is admittedly more expensive than testing a single sample. However, principles of sound experimental design demand that duplicate test samples be collected from a limited number of gross samples, and be analyzed to ensure the integrity of the test method and to determine the precision of analysis.

Moreover, a sampling program that is based on pairs of interpenetrating gross samples can easily be optimized by testing both samples only if the amount of fine gold in the first sample justifies the second test which provides a measure for the variance of sampling, sample division and measurement. The variance of analysis can be calculated from the mean of absolute differences between duplicates in test samples from a limited number of gross samples that should contain higher than average amounts of fine gold.

Correlation-regression analysis can be applied to determine the total variance and the variance of division and measurement for samples that show only small amounts of fine gold in the tailings. This approach would optimize the cost for the sampling program.

4.6. Sampling Regime

The sampling regime specifies the number of primary increments, their average mass, and the spacing between increments. In this case only a constant time based sampling regime applies. The sampling regime is based on a number of premises. Firstly, the probability for coarse gold particles to escape from the sluice box should be extremely low. Secondly, plus 8 mesh fractions should be checked for coarse gold particles either during sampling or after the sampling unit is processed. Thirdly, minus 8 mesh fractions of the tailings are expected to contain all fine gold.

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For fine gold in tailings the mass of a primary increment need not exceed 0.25 kg. In fact, a larger mass will have little impact on the sampling variance. After all, each primary increment contains such a large number of particles that the composition variance component of the sampling variance is much lower than its distribution variance. As a consequence, the number of primary increments rather than their average mass determines the sampling variance, and thus the intrinsic precision of each gross sample. The actual mass of each increment depends on the design and operational parameters for the sampling device. This matter will be addressed in Chapter 5. Sampling.

5. SAMPLING

Differences in the design and operational parameters of sluice boxes eliminate mechanical sampling of tailings so that only manual sampling will be discussed. Collecting primary increments at constant time intervals of ten (10) up to fifteen (15) minutes will generate gross samples with acceptable intrinsic precision characteristics.

The selection of the most suitable sampling interval is largely a matter of logistics. For the sampler should have enough time to collect a primary increment, to weigh and screen it on ¼" and 8 mesh sieves, and to wash plus ¼" and 8 mesh fractions. From time to time coarse fractions from a series of primary increments should be checked for the presence of coarse gold. Finally, minus 8 mesh fractions from odd- and even-numbered primary increments should be combined into a pair of interpenetrating gross samples. The sampling crew should have enough time to complete these tasks while maintaining the sampling regime.

A sampling regime that is based on collecting a pair of interpenetrating gross samples from each sampling unit should be applied. For the mean of absolute differences between measurements on such paired samples is a measure for the variance of sampling, division and testing. Duplicate of replicate test samples from single gross samples can only be used to calculate the variance of division and testing. Unless interpenetrating gross samples are collected neither the total variance nor the sampling variance can be estimated. Yet, the sampling variance is the largest component of the total variance, and the most variable parameter in this sampling program.

The volume of primary increments, and thus the mass of solids in each, is a function of the handling capacity for the sluice box, the width of the sampling device, and the speed with which it is passed through the slurry flow. Its slot should be wide enough to collect increments that are unbiased for fine gold contents. The length of the slot in the cutter should not be less than 12" to ensure that even at the highest handling capacities a full cross section of the slurry flow is collected.

A sampling device with a width of 3/8" up to 5/8" will collect unbiased increments while rejecting coarse particles. For placer operations that process screened gravels at capacities in excess of 2,500 gpm a cutter width of 3/8" will suffice. Sluice boxes that process unscreened gravel at low capacities should be sampled with the cutter adjusted to a width of 5/8". For the lowest handling capacities and slurry densities the speed of the cutter should be decreased or its width increased to ensure that each primary increment contains a sufficiently large number of elementary particles.

The sampling device in Figure A1 of Appendix A is suitable for a wide range of handling capacities. At high capacities a rubber hose should be attached so that the primary increment discharges into a shallow launder which is placed at a location that is conveniently accessible but protected against spillage and contamination. The inside of the rubber hose should not be corrugated but smooth. With a short and closed piece of hose attached the volume of the primary cutter is large enough to contain a single primary increment at low flow rates.

The handling capacity and the presence of a grizzly determine whether the sampling device requires support during its travel through the slurry. If the coarse gravel were removed by screening, and if the handling capacity were low, it may well be possible to sample without suspending the device from a chain or a cable but at high capacities a pair of brackets with a cross member will be required. Figure A2 of Appendix A shows how such a frame, when attached to the end of the sluice box, will support the primary cutter.

Removal of coarse gravel by screening would make the tailings from the sluice box simpler and safer to sample. Ironically, a sluice box that processes unscreened gravel does not collect fine gold very efficiently, and is therefore a prime target for the sampling program. Figure A3 of Appendix A shows a suitable technique to screen the slurry at the end of the sluice box, and to divert the tailings flow from the trajectory of the coarse gravel. This set-up would make it safe for the sampler to collect primary increments from the tailings of unscreend gravels.

A sampling device that has a width of 5/8" (16 mm), and that is passed through a slurry flow with a speed of 36 inch per second (ips) will collect from V gallons per minute (gpm) primary increments with a volume that can be calculated with the following formula:

$$\Delta V = (V * w)/[60 * v(s)]$$

in which: ΔV = volume of primary increment in gallons
V = slurry flow in gpm
w = width of sampling device in inches
$v(s)$ = speed of sampling device in ips

Application of this formula to a sampling device with a width of either 3/8" or 5/8" which is passed through a slurry flow at a uniform speed of 36 ips at a slurry flow that range from 1,000 gpm up to 5,000 gpm results in the following volumes of primary increments:

TABLE 5.1 - PRIMARY INCREMENT in gallons

CAPACITY in gpm	3/8"	5/8"
1,000	0.17	0.29
2,000	0.35	0.58
3,000	0.52	0.87
4,000	0.69	1.16
5,000	0.87	1.45

The amount of solids in primary increments is expected to range from a low of 5% to a high of 25%. Conversion of volumes in gallons into kg for different capacities, percentages solids and slurry densities on the basis of 3.55 liters to the US gallon and a cutter width of 3/8" results in the following amounts of dry solids in primary increments:

TABLE 5.2 - PRIMARY INCREMENT in kg - WIDTH : 3/8"

SLURRY DENSITY →	1.05	1.10	1.15	1.20	1.25
PERCENT SOLIDS →	5%	10%	15%	20%	25%
CAPACITY in gpm					
1,000	0.03	0.07	0.10	0.14	0.19
2,000	0.06	0.13	0.21	0.29	0.38
3,000	0.10	0.20	0.31	0.43	0.57
4,000	0.13	0.27	0.42	0.58	0.75
5,000	0.16	0.33	0.52	0.72	0.94

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In Table 5.3 are listed amounts of dry solids in primary increments that are collected with a 5/8" cutter:

TABLE 5.3 - PRIMARY INCREMENT in kg - WIDTH : 5/8"

SLURRY DENSITY →	1.05	1.10	1.15	1.20	1.25
PERCENT SOLIDS →	5%	10%	15%	20%	25%
CAPACITY in gpm					
1,000	0.05	0.11	0.17	0.24	0.32
2,000	0.11	0.23	0.36	0.49	0.64
3,000	0.16	0.34	0.53	0.74	0.97
4,000	0.22	0.45	0.71	0.99	1.29
5,000	0.27	0.57	0.89	1.24	1.61

Tables 5.1, 5.2 & 5.3 can be used to estimate volumes and dry solids for different sampling regimes and handling capacities. Single primary increments should not contain less than 0.2 kg of dry solids on the average to ensure that a sufficient number of fine gold particles is collected. Under certain conditions this criterion can only be met if the sampler collects primary increments at a lower speed or with a wider slot.

The sampler should develop the ability to move the sampling device through a slurry flow at constant speed. The actual speed can be checked against real time in terms of the single second that is required to travel the distance of three (3) feet for a typical sluice box at a speed of 36 ips by voicing "twenty-one" at a timed speed.

If a sluice box were to process gravel with a water flow of 1,000 gpm, if the slurry were to contain 5% dry solids, and if the cutter width were 5/8", then the sampler should operate the primary cutter at a speed of 9 ips to obtain primary increments that contain 0.2 kg of dry solids on the average. The parameters in Table 5.2 & 5.3 show which combinations of flow rates and slurry densities require a cutter speed of less than 36 ips, or a cutter width of more than 5/8".

Under such conditions a sampling regime that is based on a constant time interval of ten (10) minutes generates interpenetrating gross samples that each consist of twenty-four (24) primary increments. The

volume of each gross sample is about: 24 * 0.29 * 4 = 28 gallons, and contains approximately: 24 * 0.20 = 5 kg of dry solids.

If a sluice box were to process gravel with a water flow of 5,000 gpm, if the slurry were to contain 25% dry solids, if the cutter width were 3/8", and if it were operated at a speed of 36 ips, the volume of each gross sample would be about: 24 * 0.87 = 21 gallons, and would contain approximately: 24 * 0.94 = 23 kg of dry solids.

These calculations show that the amount of dry solids in each gross sample generally ranges from 5 kg up to 25 kg. Estimates are based on flow rates of 1,000 gpm and 5,000 gpm, and percent solids of 5% and 25%. Collecting primary increments at a speed of less than the maximum of 36 ips, and increasing the width of the cutter opening to more than 5/8", are measures to control the mass of each interpenetrating gross sample. Such changes will have less impact on the sampling variance than a change in the time interval, and thus in the number of primary increments that constitutes a gross sample.

Screening primary increments immediately after collection, and dividing sets of primary increments at intervals of two (2) up to four (4) hours if the slurry volume would become too large, are part of the sample preparation procedures that will be reviewed in Chapter 6. Preparation.

6. PREPARATION

Sample preparation is the process of screening primary increments into plus and minus 8 mesh fractions, mixing and dividing gross samples into subsamples, and collecting test samples from a gross sample or from a subsample. Each step should be carried out without introducing a systematic error and with the least possible loss of information which implies that the variance for each phase should be as low as possible. In the following sections preparation procedures for slurry samples from tailings will be described.

6.1. Primary Increments

Primary increments should be processed immediately after collection. Each increment should be weighed with a scale that has a precision of no less than five (5) grams, and then screened on a ¼" sieve to remove large particles that would damage the 8 mesh sieve which is used to obtain the slurry sample for further testing. A small double-deck vibrating screen would be suitable for this preparation step. Upon completion of screening and washing both plus ¼" and plus 8 mesh fractions are weighed after the excess water is drained. Consideration should be given to collecting a subsample from the combined fractions for a sampling unit, and storing it in plastic bags to determine moisture at a later stage.

Plus ¼" fractions should be inspected for nuggets but the probability that coarse gold will be present is extremely low. Any plus ¼" gold particles should be kept separate, weighed and accounted for when calculating the gold content of the tailings for this sampling unit. Plus 8 mesh fractions should also be checked for the presence of fine gold. Passing each composite of plus 8 mesh fractions from interpenetrating primary increments over a laboratory Deister table at the end of the sampling shift, and retaining both table concentrates for further evaluation at the testing laboratory in Whitehorse, would be the most effective procedure to account for the amount of gold in the minus ¼" to plus 8 mesh fractions.

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Minus 8 mesh composites are obtained by combining slurry fractions from odd- and even-numbered primary increments into a pair of sample containers. A detergent should be added to each container at the start of the shift to reduce surface tension so that supernatant water can be siphoned from the slurry at times without a loss of gold flakes or very fine gold particles.

Unless small enough for transportation interpenetrating gross samples should preferably be divided after a sampling unit is processed. At high capacity placer operations the volume of an interpenetrating gross sample may become so large that intermediate division of partial samples may be required. Hence, a Vezin divider should be available to divide those gross samples that are too large for transportation to the testing laboratory in Whitehorse.

6.2. Gross Samples

A small Vezin divider with four (4) slots that collects 10% of the feed for a subsample should be used to divide gross samples into sample and reject flows either in the field or in the testing laboratory. Figures A4 & A5 in Appendix A show the design and operational parameters for the Series 4300 Vezin dividers. Model 4314 would be most suitable for this application.

During division of gross samples in the field the division ratio should not exceed 1:10 to ensure that the degree of correlation between paired measurements on reject and sample flows remains highly significant, and that the variance for this division stage is significantly lower than the total variance.

A holding tank with a mechanical stirrer is required to mix gross samples prior to division. This vessel should preferably be made of stainless steel. For the fine gold will settle so solidly on a pitted and scaled surface that it becomes difficult to suspend it again by mixing. Although the nature and magnitude of the resulting systematic error depends on a number of factors, a loss of fine gold at this stage could

have a significant impact on the results of this test program. The possibility for such a bias to occur should be taken into account when selecting the holding vessel, the containers in which interpenetrating samples are stored on the site, and the containers that are used for storage and transportation of samples to the testing laboratory.

After a sampling unit is processed a pair of interpenetrating gross samples may require division into rejects that are discarded, and an unbiased subsample that is stored in a suitable container. The Vezin divider and the holding vessel, which are initially used in the field to divide large gross samples into subsamples, can be used again in the laboratory to collect test samples from gross samples or subsamples.

At high capacities partial gross samples may require division before the entire sampling unit is processed. The criterion is that the volume of a partial gross sample should not exceed the capacity of the holding vessel. After a sampling unit is processed subsamples from all partial gross samples should be combined into a composite sample such that a pair of interpenetrating composites represents the entire sampling unit.

6.3. Test Samples

The laboratory in Whitehorse should be set up to collect unbiased test samples from subsamples with the Vezin divider and the holding vessel that were used on the site to divide interpenetrating gross samples that were too large for transportation to the testing laboratory. Unless rejects from the division stage are immediately returned to the original sample container an additional holding vessel may be required to collect such rejects.

If a 10% test sample is too small for testing on a laboratory Deister table, additional division cycles will be required to obtain a sufficiently large test sample. Upon completion of division composite test samples should be mixed to ensure homogeneity. Carefully pouring it from one sample container into another is a most effective mixing procedure.

Initially, test samples should only be collected from subsamples that represent odd-numbered primary increments. Only in the case that the result of the first test justifies a second measurement, will it be necessary to collect a test sample from the subsample that represents even-numbered primary increments. The decision to test odd-numbered increments first is strictly arbitrary but the final choice should be consequential throughout the sampling program.

Each test sample is collected by transferring the gross sample or the subsample into the holding vessel, by mixing it carefully, and by dividing it with the Vezin divider. Rejects should be returned to the original sample container without delay. After the results for the first test sample are known a decision is made whether the amount of fine gold in the tailings of this sampling unit is high enough to justify the testing of the other interpenetrating sample.

At that stage a larger test sample may be required for other purposes so that more division cycles will be required before rejects are returned to the original container. It is also possible that a composite sample for all sampling units from a certain placer operation are required for other tests. In such a case composites from odd- and even-numbered primary increments would still provide a measure for the variance of sampling, division and testing.

7. MEASUREMENT

The most suitable test to determine the amount of fine gold in tailings with an acceptable degree of precision, and to assess its particle size distribution, is to concentrate each test sample on a laboratory Deister table, to dry and then screen the concentrate into five (5) fractions, and to determine the gold content of each fraction.

Tailings from each test should be dewatered on a vacuum filter. The filter cake should either be dried, or its moisture content determined in a small subsample that is collected with a No 1 incremental division scoop (see Figure A6 in Appendix A), or with a small round probe. The advantage of drying a subsample only is that the remaining tailings can be suspended again without changing surface characteristics due to oxidation so that composite tailings from the Deister table can still be used for flotation tests.

The mass of the dry solids in the test sample is the sum of dry weights of table concentrate and their tailings. For each test sample this mass should be recorded. Dried table concentrates should be divided into fractions with the following set of test sieves:

TABLE 7.1 - SIZE FRACTIONS OF TABLE CONCENTRATE

SIEVE FRACTION	SIZE in microns
PLUS 28	> 1190
MINUS 28 - PLUS 48	297 - 590
MINUS 48 - PLUS 100	149 - 297
MINUS 100 - PLUS 200	74 - 149
MINUS 200	< 74

Important characteristics such as the shape of gold particles in each fraction should be classified and recorded before its gold content is determined by fire assaying. Plus 100 mesh fractions should preferably not be subsampled but assayed in their entirety to avoid the single particle effect on the precision of analysis. If the mass of a fraction is larger than 30 grams, the placer laboratory in Whitehorse could collect two (2) test samples of about ½ assay ton each so that the precision of analysis for gold can be estimated.

Test samples for gold assays should be submitted to a reputable assay laboratory in small vials. Each test sample should weigh between ¼ and 1 assay ton (about 7.5 up to 30 grams). The assay laboratory should be instructed to fire assay the entire test sample after its exact weight is determined.

The precision of analysis for gold in the plus 100 mesh fractions can be improved by comminuting each fraction with a vibratory ring pulverizer, and then screening it on a 150 mesh sieve. Repeatedly pulverizing and screening would result in plus 150 mesh metallics that can be wrapped in lead foil and cupelled directly, and a minus 150 mesh fraction in which gold can be determined with a much higher degree of precision than in the original fraction. Unless the mass of a fraction is much larger than thirty (30) grams precious little information will be gained despite much higher costs for preparation and analysis. Moreover, reducing the variance of analysis would not impact significantly on the variance of fine gold contents in the tailings of sampling units.

Each fraction should be carefully mixed by coning with a pair of small stainless steel mixing trays before a test sample for the fire assay is collected. Incremental division with a small scoop (see Figure A7 in Appendix A) or spatula with a square tip should be applied to collect test samples from table concentrate fractions. The placer testing laboratory in Whitehorse should collect such test samples rather than submit complete size fractions of table concentrates for fire assaying.

The advantage of this approach is that test samples for fire assaying are collected under carefully controlled conditions and in a reproducible manner. The objective is to ensure that the variance for this division stage remains a small part of the total variance, and that systematic errors are avoided. Variance components for collecting test samples from size fractions, and for fire assaying, constitute only a small part of the total variance. Hence, the effect of random variations in these phases on the precision for the average amount of gold in the tailings will be a small and most probably insignificant component of the total variance for the measurement process.

After all tests for one interpenetrating gross sample are completed, the relevance of its gold content should be assessed against other sampling units from the same placer deposit that were processed at different times, or against different placer deposits in the same region. Only for those sampling units that showed a commercially significant amount of fine gold in the tailings on the account of test results for the first interpenetrating gross sample, should the second sample be tested for its gold contents.

In the case that all sampling units from a certain placer deposit show commercially significant amounts of fine gold in the tailings, additional testing will be required to assess the effectiveness of different recovery techniques. A pair of composites should then be prepared such that one composite consists of subsamples from all odd-numbered primary increments while the other consist of subsamples from all even-numbered increments. Testing such pairs of composites provides a measure for the precision of each technique so that differences between techniques can be checked for statistical significance.

8. EXPERIMENTAL DESIGN

The design of the sampling program is based on a hierarchy of nested classes. Placer regions are the highest class, and primary increments are the lowest class. The objective is to measure the quality parameter of interest in the most efficient way. Figure B1 in Appendix B is a flow chart in which all nested classes for this design are displayed.

Testing each primary increment of the set that represents a sampling unit for gold contents would provide the ultimate amount of information so that averages for the next class (sampling units), and for higher classes (strata, sections, placers) can be compared most effectively. However, the cost for testing single primary increments is prohibitive.

Testing single gross samples only does not allow for the comparison of averages of sampling units. For this design does not generate an estimate for the variance of sampling, division and testing. Hence, it is impossible to assess whether averages for two (2) or more sampling units are compatible and thus statistically identical, or whether they differ significantly.

Testing interpenetrating gross samples generates only marginally less information than testing primary increments. However, the costs for a sampling program that is based on interpenetrating samples compares favorably with the single gross sample alternative. Thus a sampling program that is based on collecting interpenetrating samples, is an efficient compromise between the cost for the sampling program and the amount of information that it generates.

Such considerations imply that the sampling program should preferably be based on collecting a pair of interpenetrating gross samples from each sampling unit. The incremental cost for collecting a pair of samples rather than a single sample is low but preparing and measuring pairs of samples costs twice as much. However, this cost can be reduced by testing the second sample only if the amount of fine gold in the tailings of sampling units from a particular placer operation is commercially significant.

- cont'd -

This experimental design is based on the relationship between the mean of absolute differences between test data for interpenetrating samples and the variance of sampling, division and measurement. The mean of absolute differences is a function of the average amount of fine gold in tailings. In fact, the degree of correlation between differences and corresponding gold contents is invariably significant to the extreme so that it can be used to estimate the variance of sampling, division and testing for lower gold contents.

Simulated test data will be used in numerical examples of precision calculations. Table 8.1 shows a complete data set for a single pair of interpenetrating gross samples. Such a data set would imply that this gold content of 5.8 oz/st, which was measured in a table concentrate from a test sample of a gross sample that consists of the odd-numbered primary increments, is of commercial significance, and thus that the gold content of 5.1 oz/st was obtained in the even-numbered primary increments from the same sampling unit.

In Table 8.1 are listed gold assays in the five (5) fractions of a table concentrate that was obtained from a pair of test samples together with their average gold contents:

TABLE 8.1 - MASS OF FRACTIONS in % - GOLD ASSAYS in oz/st

SAMPLE TYPE	ODD INCREMENTS		EVEN INCREMENTS	
SIEVE FRACTION	percent	oz/st	percent	oz/st
PLUS 28	26.0	6.5	29.7	6.8
MINUS 28 - PLUS 48	20.8	11.3	18.5	9.7
MINUS 48 - PLUS 100	14.2	8.9	12.4	8.1
MINUS 100 - PLUS 200	12.8	3.1	11.9	2.2
MINUS 200	26.2	0.27	27.5	0.21
WEIGHTED AVERAGE in oz/st		5.8		5.1

The difference of 0.7 oz/st is a measure for the variance of sampling, division and measurement of a table concentrate that was obtained from a single test sample. Additional sampling units from the same placer deposit that were processed and sampled at different times provide additional information on the variability between sections.

- cont'd -

In Table 8.2 are listed simulated test data for additional sampling units:

TABLE 8.2 - GOLD ASSAYS FOR DIFFERENT SAMPLING UNITS

SAMPLING UNIT	ODD	EVEN	AVERAGE	|DIFF|
PLACER X - 1	2.4	2.1	2.25	0.3
PLACER X - 2	7.3	6.5	6.90	0.8
PLACER X - 3	4.8	5.4	5.10	0.6
PLACER X - 4	6.9	6.2	6.55	0.7
PLACER X - 5	5.8	5.1	5.45	0.7
AVERAGES			5.25	0.62

Application of correlation-regression analysis to this set of paired data results in the following statistical parameters:

TABLE 8.3 - STATISTICAL PARAMETERS FOR GOLD CONTENTS

PARAMETER	SYMBOL	VALUE
CORRELATION COEFFICIENT	r	0.977
SLOPE	b	0.102
INTERCEPT	a	0.082

Based on these sampling units a realistic estimate for the mean of absolute differences at an average gold assay of 5.45 oz/st is: 5.45 * 0.120 + 0.082 = 0.736 oz/st which is equal to a variance of sampling, division and testing of: $(\pi/4) * 0.736^2 = 0.425^2$, a standard deviation of: $0.425^{\frac{1}{2}} = 0.652$ oz/st, and a coefficient of variation of: $0.425^{\frac{1}{2}} * 100/5.45 = 12.0\%$.

On the basis of this standard deviation of 0.652 oz/st and the rounded z-value of 2 from the normal distribution the 95% confidence interval for a single test sample is: 2 * 0.652 = ± 1.30 oz/st for a 95% confidence range from: 5.45 - 1.30 = 4.1 oz/st up to: 5.45 + 1.30 = 6.8 oz/st.

For the mean of a pair of interpenetrating gross samples the precision for this gold assay of 5.45 oz/st the variance is: 0.425/2 = 0.213 for a standard deviation of: $0.213^{\frac{1}{2}} = 0.46$ oz/st, and a CV of: $0.213^{\frac{1}{2}} * 100/5.45 = 8.5\%$. In this case the 95% CI is: 2 * 0.46 = ± 0.92 oz/st for a 95% CR from: 5.45 - 0.92 = 4.5 oz/st up to: 5.45 + 0.92 = 6.4 oz/st.

- cont'd -

The numerical examples in this chapter are valid for table concentrate only. If these parameters were valid for the gold assays in pairs of interpenetrating gross samples, and if each gross sample consisted of twenty-four (24) primary increments (collected at sampling intervals of ten minutes for eight hours), then a conservative estimate for the sampling variance would be: $24 * 0.425 = 10.2$ $(oz/st)^2$.

An estimate for the variance of division and analysis can be obtained by collecting and testing duplicate test samples from the same subsample. If the mean of absolute differences between duplicate test samples from the same subsample were 0.15, the variance of division and measurement is: $(\pi/4) * 0.15^2 = 0.018$. Deduction of this variance from the total variance of 0.425 results in a sampling variance of sampling of 0.408 so that a more realistic estimate of the sampling variance is: $24 * 0.408 = 9.8$ $(oz/st)^2$. Some allowance could be made for the variance component that is due to collecting subsamples from gross samples.

The variance of 9.8 $(oz/st)^2$ would be a measure for the variability of fine gold in tailings. Hence, gold contents of single primary increments are expected to range from a low of: $5.45 - 2 * 9.8^{\frac{1}{2}} = 0$ oz/st up to a high of: $5.45 + 2 * 9.8^{\frac{1}{2}} = 12$ oz/st in 95 out of 100 increments.

The metallurgical balance for a sampling unit requires that the following parameters be measured and recorded:

1. volume of sampling unit in yd^3
2. volume of coarse gravel from grizzly in yd^3 (optional)
3. volume of water used during sampling period in gallons

4. mass of each primary increment in kg
5. mass of plus ¼" fraction in kg
6. mass of minus ¼" to plus 8 mesh fraction in kg
7. mass of test sample for Deister table in kg
8. mass of table concentrate fractions in kg
9. gold assays of fractions in oz/st

The sampling program is designed to measure fine gold in the tailings of sampling units. Head grades of sampling units can only be estimated if coarse gold that was recovered with the sluice box could be measured accurately and with an acceptable degree of precision.

It is unrealistic to expect that the sluice box can be cleaned after each sampling unit is processed. However, it may well be possible to clean the sluice box before and after all sampling units at a particular placer operation are processed so that coarse gold can then be allocated to each sampling unit on the basis of its fine gold contents.

Ideally, sampling units should be spaced over the longest possible period of time which translates into visiting selected placer operations in rotation. Logistics of the field work and cost considerations dictate that each placer operation can only be visited once. Unless an operator is prepared to process gravel from different sections of his placer during the test program the variability between consecutive sampling units will be significantly lower than between widely spaced sampling units. The variability between sampling units becomes relevant at a later stage when the average gold content of the tailings from a certain placer should be known with the highest possible degree of precision.

APPENDIX A

FIGURES

FIGURE A1 - PRIMARY CUTTER

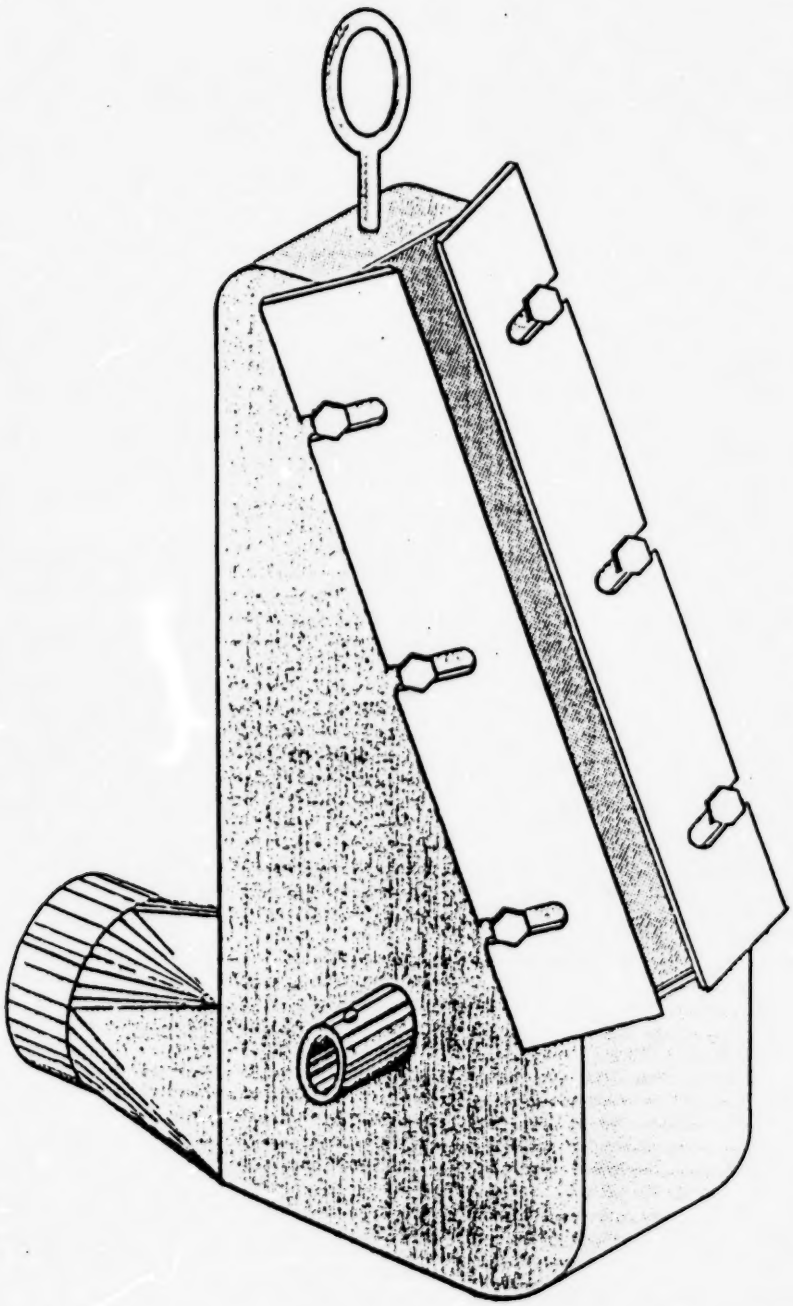


FIGURE A2 - SAMPLING OF SCREENED GRAVEL

FIGURE A3 - SAMPLING OF UNSCREENED GRAVEL

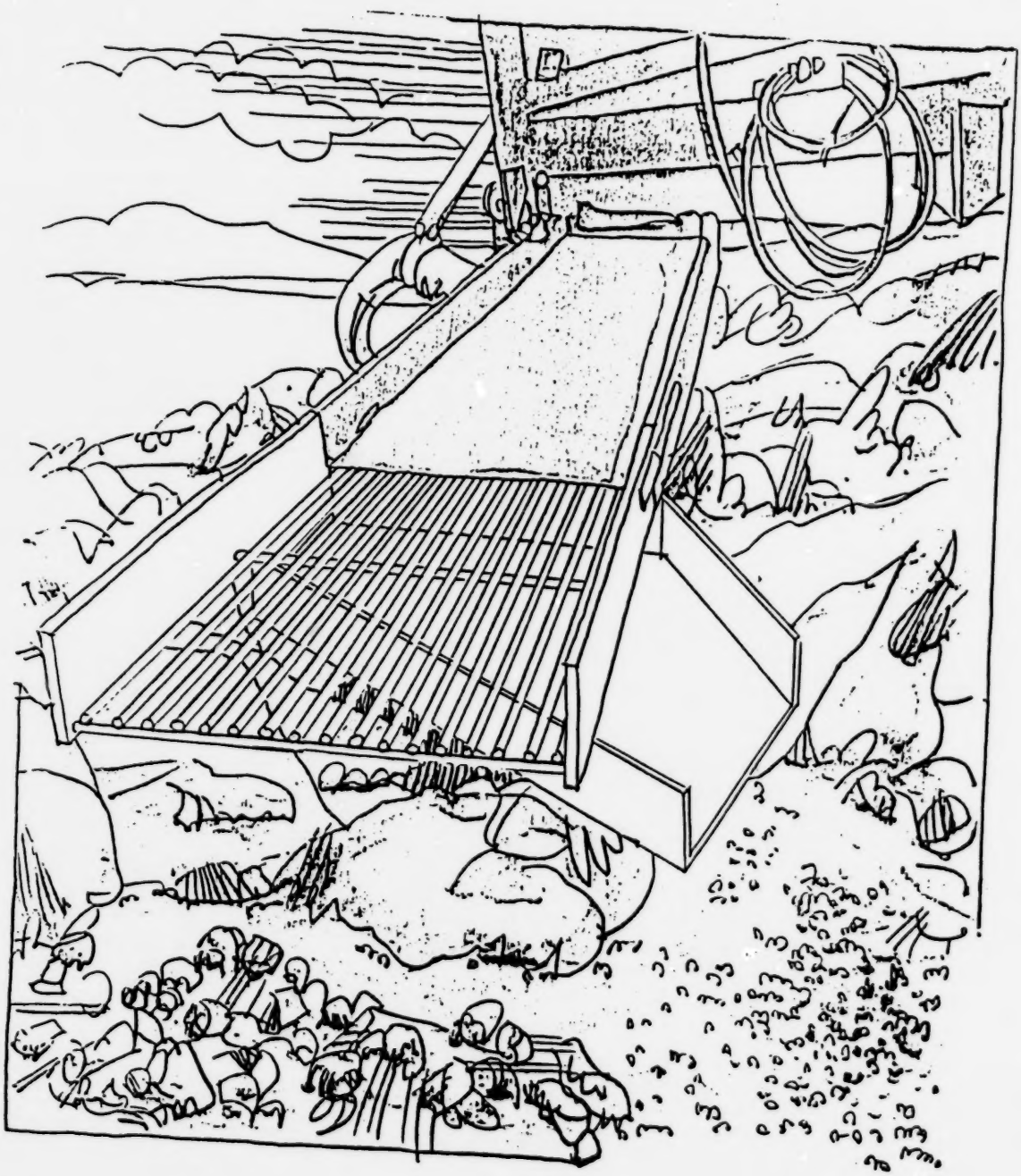
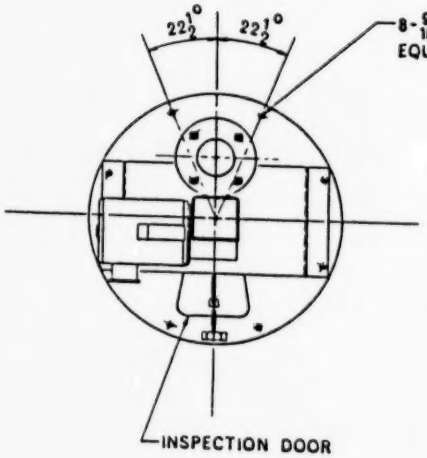
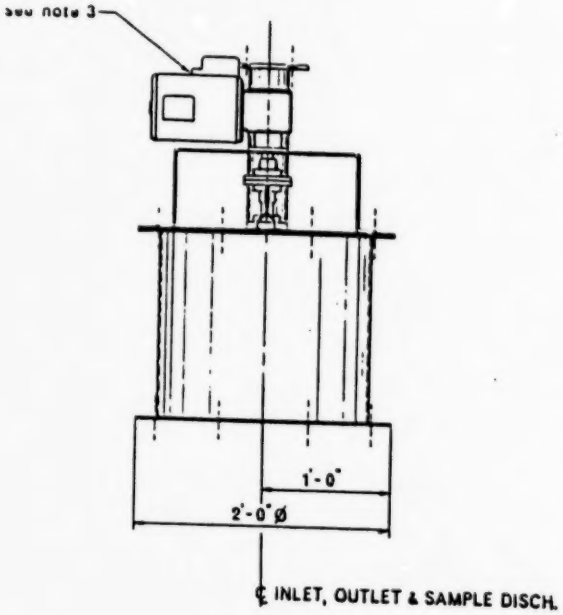


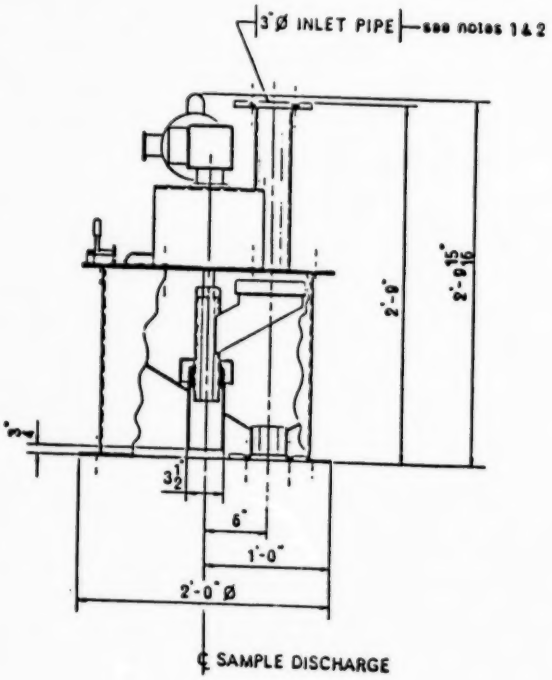
FIGURE A4 - VEZIN DIVIDER



NOTES:

1. Drilling pattern of inlet and outlet flanges is identical.
2. Refer to section 9000, sheet 9000-1 for flange bolting patterns.
3. Motorized reducer, ¼ HP at 25 RPM output speed.



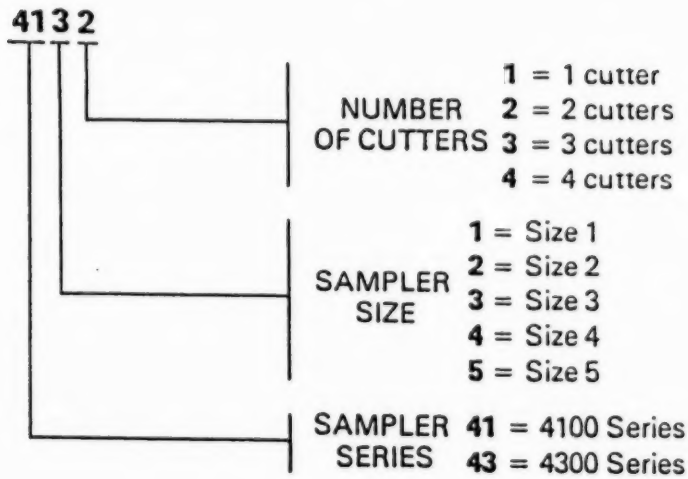


MODEL 4300 CONTINUOUS VEZIN SAMPLER

FIGURE A5 - MODEL 4314 : 10% DIVISION RATIO

MODEL CODE BREAKDOWN

EXAMPLE:

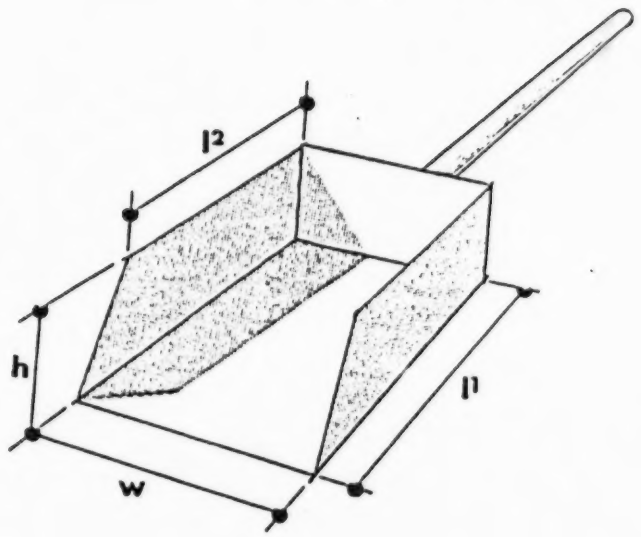


In this example a model **4132** = a model 4100 sampler, size three, with two cutters.

MODEL SIZE TABLE

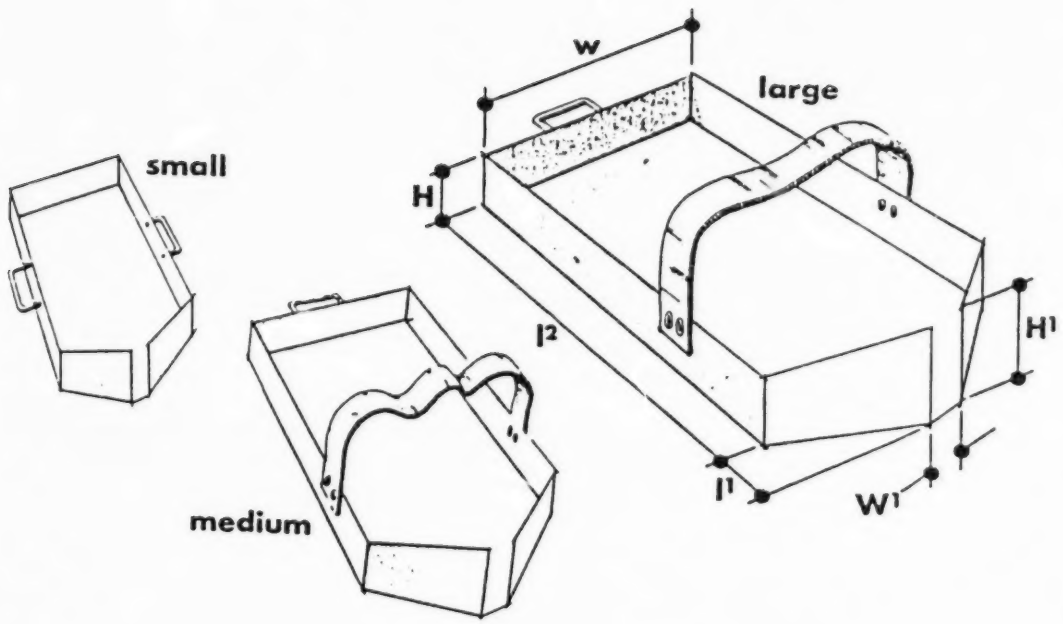
MODEL	*SPEED OF ROTATION (RPM)	*CUTTER VELOCITY (ips)	WEIGHT (lb.)	REFERENCE SHEET NO.
4111	25	15.7	375	4111-1
4121	20	16.8	500	4121-1
4131	11	13.8	800	4131-1
4141	9	14.1	1450	4141-1
4151	9	17.0	2075	4151-1
4311	25	15.7	350	4311-1

FIGURE A6 - INCREMENTAL DIVISION SCOOP



SCOOP NO.	TOPSIZE IN mm	VOLUME IN ml	DIMENSIONS IN mm				THICKNESS IN mm STAINLESS STEEL
			w	h	l1	l2	
1	1	15	30	15	30	25	.5
3	3	40	40	25	40	30	.5
5	5	75	50	30	50	40	1
10	10	125	60	35	60	50	1
15	15	200	70	40	70	60	2
20	20	300	80	45	80	70	2
30	30	400	90	50	90	80	2
40	40	800	110	65	110	95	2
50	50	1700	150	75	150	130	2

FIGURE A7 - STAINLESS STEEL MIXING TRAYS



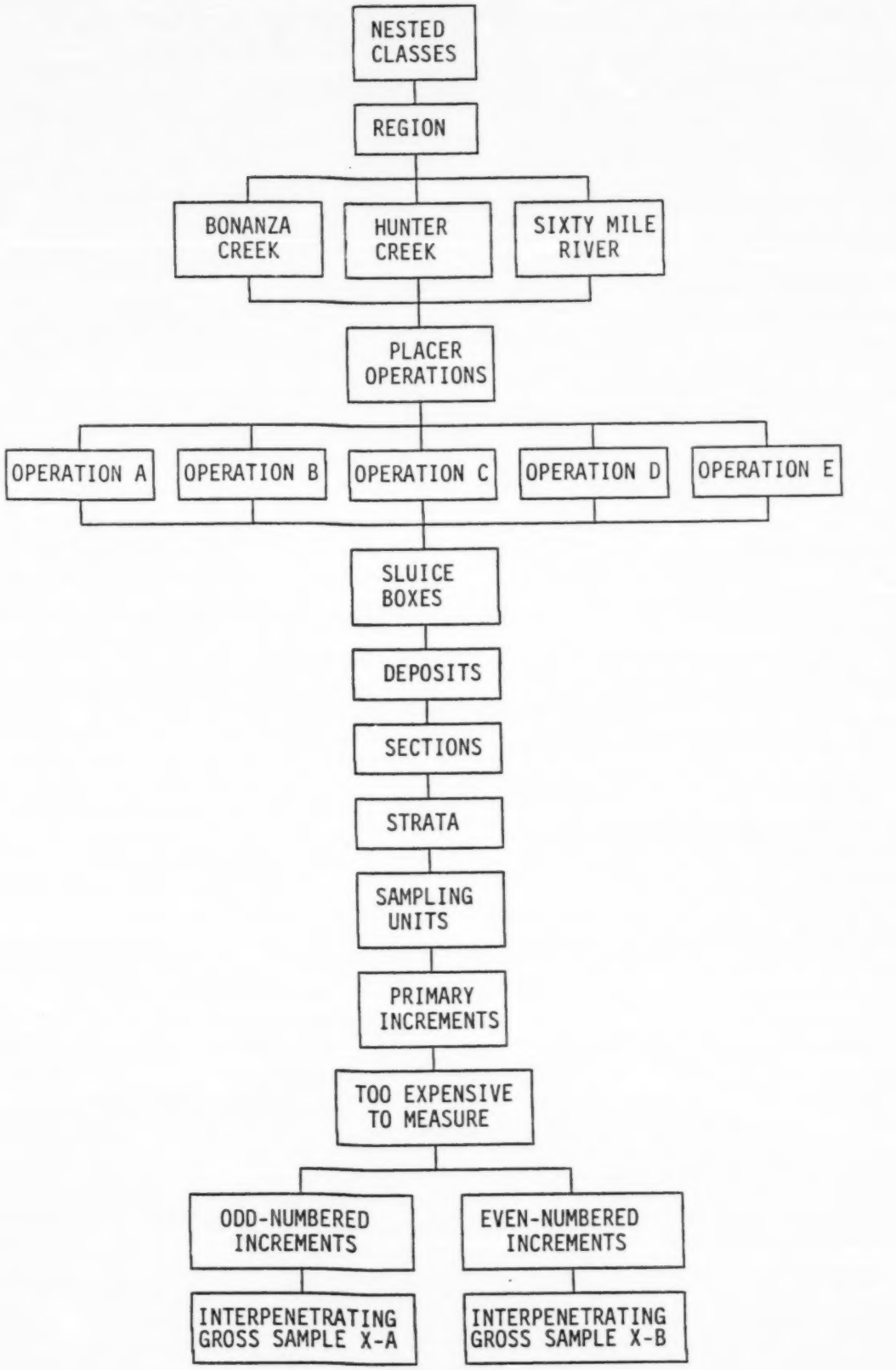
MEASURES IN MM	SMALL	MEDIUM	LARGE
L1	100	200	300
L2	200	400	600
W	150	250	400
W1	25	50	100
H	25	50	100
H1	50	100	150
Thickness	1	1.5	2

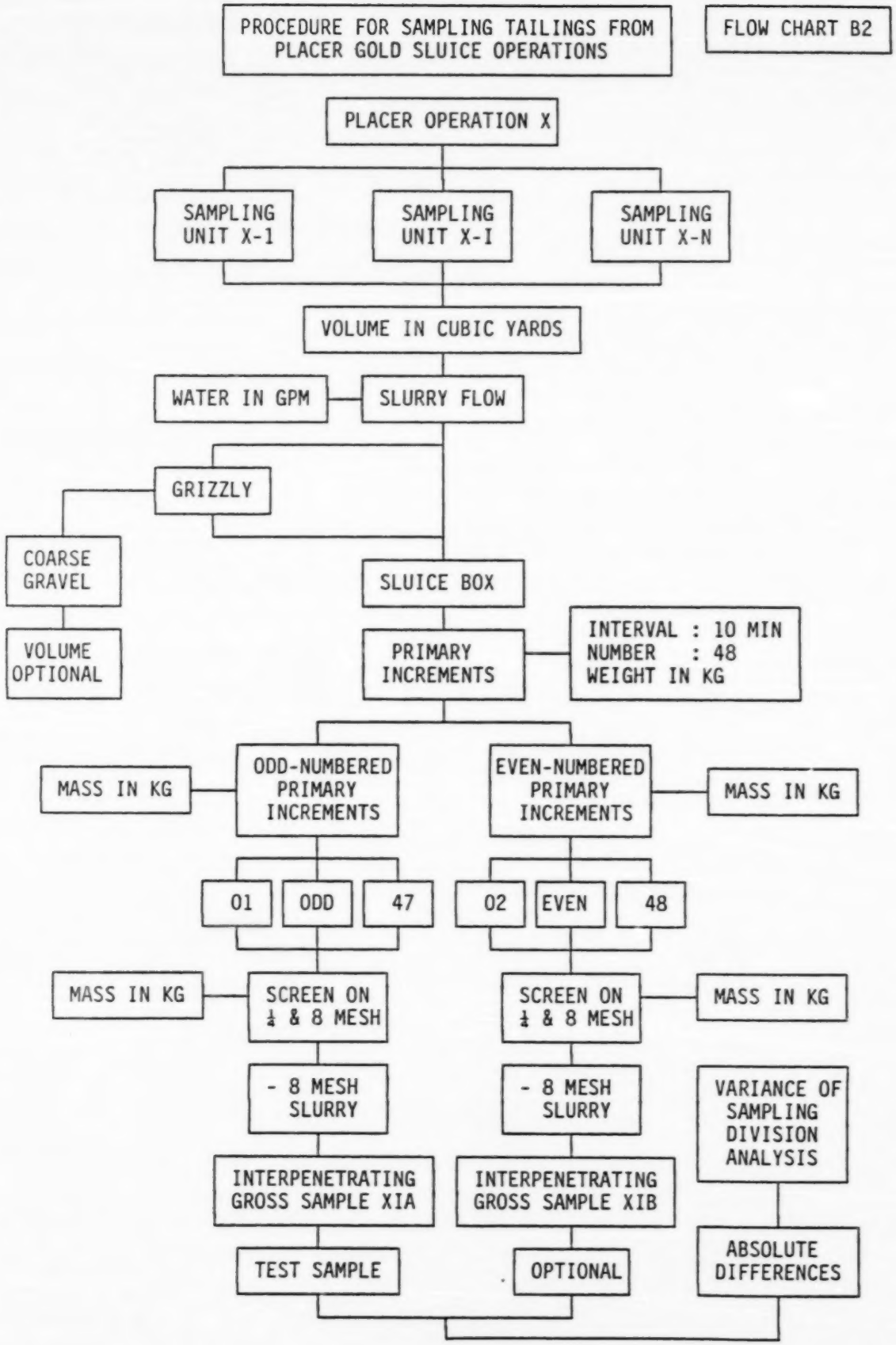
APPENDIX B

FLOW CHARTS

PROCEDURE FOR SAMPLING TAILINGS FROM PLACER GOLD SLUICE OPERATIONS

FLOW CHART B1




PROCEDURE FOR SAMPLING TAILINGS FROM PLACER GOLD SLUICE OPERATIONS
FLOW CHART B2
PLACER OPERATION X
SAMPLING UNIT X-1
SAMPLING UNIT X-I
SAMPLING UNIT X-N
VOLUME IN CUBIC YARDS
WATER IN GPM
SLURRY FLOW
GRIZZLY
COARSE GRAVEL
VOLUME OPTIONAL
SLUICE BOX
PRIMARY INCREMENTS
INTERVAL : 10 MIN
NUMBER : 48
WEIGHT IN KG
MASS IN KG
ODD-NUMBERED PRIMARY INCREMENTS
EVEN-NUMBERED PRIMARY INCREMENTS
MASS IN KG
01
ODD
47
02
EVEN
48
MASS IN KG
SCREEN ON ¼ & 8 MESH
SCREEN ON ¼ & 8 MESH
MASS IN KG
- 8 MESH SLURRY
- 8 MESH SLURRY
VARIANCE OF SAMPLING DIVISION ANALYSIS
INTERPENETRATING GROSS SAMPLE XIA
INTERPENETRATING GROSS SAMPLE XIB
TEST SAMPLE
OPTIONAL
ABSOLUTE DIFFERENCES